Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 57 (2014) 2984 – 2993

Energy Procedia

2013 ISES Solar World Congress

NOPAL (*Opuntia Lasiacantha*) DRYING USING AN INDIRECT SOLAR DRYER

Adolfo G. Finck-Pastrana

Solar Thermal Energy Laboratory,
Physics and Mathematics Department,
Universidad Iberoamericana, Ciudad de México.
Prol. Paseo de la Reforma #880, Lomas de Santa Fé,
C.P. 01219, México, D.F. MÉXICO.
Tel.: (52)(55)(5950-4085), Fax.: (52)(55)(5950-4284).
e-mail: adolfo.finck@ibero.mx

Abstract

Water contained in foods allows the proliferation of microorganisms and the development of chemical reactions that deteriorate. When required preserve food for a time, a dry or dehydrate alternative is removing the water contained therein. There are several ways to achieve this issue, the simplest is to exposed the food into a stream of air with certain conditions of temperature, humidity and velocity. There are several types of solar dryers to achieve proper product treatment. The two basic elements of a solar dryer are manifold where solar radiation heats the air and the drying chamber where the product is dried by the air passing through it, these elements can be designed to integrate the team in different forms. In an indirect solar dryer the two elements are separated, the air is heated in the manifold so that no solar radiation incident on the product placed inside the opaque drying chamber, in this type of dryers the process control drying is simpler. Having a separate drying chamber manifolds facilitates handling of the product and the work of loading and unloading. Since the drying chamber is opaque, this system conveniently dry products that can be damaged by direct sunlight. This project works with an indirect solar dryer having a solar air heater built into its structure with plywood wood 1" thick, both the base and sides, with dimensions of 140 cm long and 60 cm width, a cover glass thickness of 3 mm and an inclination of 17.5° to the horizontal. The main element is a coil of copper foil matt black painted placed inside the structure, isolated base and on all four sides with fiberglass wool, has thirteen channels 10 cm x 10 cm x 10 cm, which means a final length of 5 m in the warm air path, giving a conservative 0.01 m^3/s flow and a 1 m/s natural convection speed. The drying chamber is constructed of plywood wood ½" thickness and dimensions of 60 cm long, 40 cm wide and 55 cm high with four nylon mesh trays, allowing initial drying mass about 2 kg. The connection between the solar air heater and the drying chamber is performed by means of a neoprene hose with a very low thermal conductivity in its wall. Thermal efficiency is calculated by evaluating the productivity of the dryer measuring temperature, air flow, solar radiation and loss of product mass. Drying curves are obtained graphing Dry Basis Moisture vs. time (X vs. t) and Drying Rate vs. Dry Basis Moisture ($\Delta X/\Delta t$ vs. X) for Nopal (*Opuntia Lasiacanta*). It is considered that this type of dryer offers several advantages over the common cabinet druer, including the drying rate and product protection from direct sunlight.

Selection and/or peer-review under responsibility of ISES.

Keywords: Nopal; Drying; Foods; Solar Dryers; Health

Selection and/or peer-review under responsibility of ISES.
doi:10.1016/j.egypro.2014.10.334

1. INTRODUCTION.

NOPAL (OpuntiaLasiacantha) is a species of the opuntias, of the family of cacti or prickly pears. His original name is Tenochtitlan meaning "fruit of the stone and Nuchtli", the Aztecs used it under the name of nopalli, taken by the Spaniards for finally know its current name.(1)

It is a shrub of about 5 m tall, with branched of color stem green and flat, is trunk consists of flattened stalks, covered with thorns and small removable hairs that facilitate human consumption also consists of flowers ranging from yellow to red, fruits of green, red or purple, tunas calls which are also suitable for human consumption. Its Habitat is dry, lexemic, and temperate climate, is cultivated in arid and semi-arid areas, is associated with xerophiles thickets and forests of oak and pine. It does not require much water for cultivation, so it is a good source of income for many farmers who do not have the necessary resources and living in arid or semi-arid areas. It is said that it has an important ecological role, since it stops the deforested soil degradation, i.e. it becomes unproductive land productive. There are about thousand 600 species in 122 genera of cacti, which comes from the cactus.(1)

In Mexico the yearly intake per capita of nopal is 6.4 kilos. The use of the Cactus goes back to pre-Hispanic times. It is cultivated in several States from the center of the country such as Morelos, Tlaxcala, Mexico City and the State of Mexico.(2) Within the benefits are there, we find the following:

Obesity: it has become fashionable that in all diets take a cactus with orange juice or some other fruit. This is based on that due to the large amount of fiber that has this plant, helps delay time, in which the nutrients are absorbed and enter the blood and therefore facilitates its removal. Also, insoluble fibers containing, create a feeling of fullness, making to reduce the hunger of the people and help a good digestion. Likewise, vegetable proteins promote the mobilization of fluids in the bloodstream, reducing cellulite and fluid retention.

Diabetes and hyperglycemia: increases the levels and sensitivity to insulin thus achieving steady and adjust the level of sugar in the blood. As hypoglycemic, the power of the nopal, i.e. as an effective treatment for the prevention of diabetes is scientifically proven. Research has been conducted at the National Polytechnic Institute, where it is documented that nopal lowers blood glucose concentrations. This has been only in people that they are resistant to insulin, or in patients with type II diabetes, but for people who have diabetes type I (who do not produce insulin), the consumption of prickly pear does not replace injections of this. In these studies, it has been shown that ingestion of nopal before every meal, for 10 days, causes the decrease in body weight and reduces concentrations of glucose, cholesterol and triglyceride in blood.

Cholesterol: By its high content of amino acids, fiber and niacin, nopal regulates the bad cholesterol in the blood, in people with high cholesterol has been shown that nopal consumption helps dispose of avoiding that it is absorbed much of this and thus does not accumulate in veins and arteries. Amino acids, fiber and niacin in nopal prevent excess sugar in the blood to become fat, while on the other hand, it acts metabolizing fat and fatty acids thereby reducing cholesterol. The content of LDL (low density lipoprotein) in nopal is believed that it is the main cause of cholesterol to be expelled from the body, since LDL Act at the level of the liver removing and withdrawing the cholesterol that the body has too much. At the same time has been that this amount of LDL does not affect the HDL (high density lipoprotein) or "good" cholesterol. The Cactus has one sufficient amount of amino acids and fiber, including the antioxidant vitamins C and A, which prevent the possibility of damage to the walls of the blood vessels, as well as also the formation of platelets from fat, and it is as well as it also has a preventive power in relation to atherosclerosis, (is a disease of chronic evolution, characterized by the formation of plaques of fibrous tissue and elements lipoidicos with the assistance of the platelet adhesion in) the endothelium of arteries).

Property of antibiotic:nopales are natural antibiotics, this property is associated with the crasulaceo acid metabolism (CAM) of plants, which, in the cacti it inhibits or suspends the growth of several species of bacteria. That is why both the consumption of prickly pear and the application of poultices of Cactus cladodes have beneficial effects on wounds and skin infections.

Cancer. In an experiment carried out with mice with cancerous tumors, aqueous extracts of Opuntia were given maxima (a substance that is found in nopal) and the extension of the period of latency of these malignant tumors were found. Not cured the cancer, but she stopped him. The cause is not yet known, but several studies in this regard are underway.

Gastrointestinal disorders and digestion. Vegetable fibers and the mucilage control excess gastric acid and protect the gastrointestinal mucosa, preventing gastric ulcers and all that kind of conditions, although the most recommended part for these ills is the root cooked and mixed with guayaba.

The cactus, has been characterized by granting its multiple benefits, is regarded as a source of vitamins for the high degree of content, contains vitamins A, B complex, C, minerals: calcium, magnesium, sodium, potassium, iron, and fibers in lignin, cellulose, hemicellulose, pectin and mucilage which help to eliminate toxins in conjunction with 17 amino acids. Environmental toxins caused by alcohol and cigarette smoke that suppress the body's immune system, are eliminated by the cactus. It also cleans the colon since it contains soluble and insoluble dietary fibers. Insoluble dietary fibers absorb water and accelerate the passage of food through the digestive tract and help regulate intestinal movement, moreover, the presence of fibers insoluble in the colon help to dilute the concentration of carcinogens that may be present.(2)

Figure 01.- Cladodes of Cactus separated from Bush.

Figure 02.- Clean and free of spines Cactus Cladodes.

As food is used as fodder, but also marketed the tender stalks as a vegetable, they can prepare marinated, cooked broths and soups, salads or casseroles, entrees, such as snacks, in sauces, drinks, desserts, jams and a wide range of food applications that can be given to this plant so rich in properties. The consumption of prickly pears blended with some fruit as a measure to lower weight or for persons suffering from certain diseases to be later described has been very popular recently. The only problem with this is that the mucilage is to many people a little unpleasant or baba, since it is there to make the smoothie. Dehydrated nopal or nopal powder has come to offer a solution for this problem. To avoid the prickly pear extract freezes or it slips, it is recommended also garlic, bicarbonate, husk tomato, corn, lemon juice, ash or volcanic stone in water.

In Mexico the Cactus has a very special meaning for the symbolic role of the settlement of the Aztecs in the Texcoco Lake, giving rise to his empire, Tenochtitlan (you, stone and nochtli-Cactus).

The Aztecs used it for many medicinal uses: for fevers they drank the juice, mucilage or prickly pear slime used it to heal chapped lips, hands and feet, pulp cured diarrhea, the thorns to clean infections, fruit was used for the excess of bile, they employed as hot dressing nopal stalks to relieve inflammations and root for the treatment of hernia, irritated liver, stomach ulcers and Erysipelas, seeds to reduce menstrual flow, other less common uses were for disorders of the lungs and as an aid in childbirth. It is now part of our national coat of arms and still has various medicinal and food uses.[1]

1.1 The drying.

The water contained in the food allows the proliferation of microorganisms and/or the development of chemical reactions which impair them. When it is necessary to preserve food for some time, an alternative is to dry them or dry them; i.e., remove the water contained in them.[3] There are several methods to accomplish this, the simplest is to expose food to an air stream, subject to certain conditions of temperature, humidity and speed. The moisture content of a product is expressed in relation to their total mass or its dry mass (i.e. the mass obtained discounting the mass of evaporable water containing). Thus defined:

Moisture content in damp basement:

$$M = \frac{m - m_s}{m}$$

Moisture content in dry basement:

$$X = \frac{m - m_s}{m_s}$$

In which:

m: total mass of the product.
m_s: dry mass of the product.

(M) moisture content is expressed as a percentage, while moisture (X) is proportional to the water contained in the product. Shows the relationship between the values of X and M; It can be seen that these practically coincide to low moisture content. The direct determination of the moisture content means to measure the mass of the product and the corresponding dry mass. For this last is usually remove, by applying heat, the water contained in it, taking care not to evaporate at the same time other substances of the product.

1.2 Drying curves of a product.

If drying a product were graph its moisture content dry base, X, in function of time, gets called drying curve. The curves of drying of a product depend on:

- The material of which it is constituted.
- The degree of maturity.
- Previous treatment that has received.
- The shape and size of the portions.
- The way to place it in the dryer.
- How that air makes contact with it, etc.

The graph of speed variation of X, (dX/dt), according to the own dry basis humidity X, is also very important.[4] While the bigger area of the pieces of material to be dried in relation to its volume drying is faster. The size of the parts, is also important because of it depend on the distances over which should spread the heat and humidity. The disposal of the product in the dryer is critical because it must allow the maximum exposure of the surface to air and offer the least resistance to the passage of this. The drying curves depend on the conditions of relative humidity, temperature and speed of the used air. In a certain range of temperature, speed and air humidity, drying time is reduced, increasing the temperature or air velocity or reducing its relative humidity.[5]

2. THE SOLAR DRYER.

There are different types of solar dryers, which offer producers a wide range of opportunities to achieve a proper treatment of your product. The two basic elements of a solar drier are the collector where the radiation heats the air and the drying chamber where the product is dried by air passing. These elements can be designed to be integrated into the team in different ways:[6]

2.1 Advantages and disadvantages:

Indirect Solar dryer: Control of the process is simpler (especially for drying with forced air circulation). You have a drying chamber separated from the collectors facilitates the work of loading and unloading and handling of the product. Since the drying chamber is opaque, this system allows dry convenient products that may harm or losing quality of appearance by a direct exposure to the Sun.
Separate collection of solar energy of the drying function, the size of the equipment and its costs grow. A second less apparent disadvantage is that it is needed to evaporate the same amount of water move more kilograms of air at higher temperatures than in the case of direct dryers. The solar collectors will work in a lower efficiency of its characteristic curve point, which leads to greater catchment areas of energy. For bulk goods mainly grains in silo if the solar drying, the system to be used is an indirect dryer.[6]
Direct solar dryers: In solar dryers direct radiation is absorbed by the product itself, resulting in more effective the use of energy to produce the evaporation of the water. This is because the steam pressure in the surface of the product grows by the absorption of solar radiation. Gradient between product and air vapor pressures becomes greater and accelerates drying. The combination of collector and camera into a single unit may be more economical in many cases, especially in smaller-sized dryers.

This type of dryer is almost always with natural convection air circulation. This makes control of the process is sometimes unreliable. It is common to see over in this type of dryer temperature increases, leading to enzymatic Browning. For some products the action of solar radiation can destroy any organic compound which composes and has commercial interest.

3. DESCRIPTION OF THE SYSTEM.

In this project Nopal drying is performed with an indirect Solar dryer where you have the ability and choice of directing the flow of hot air from the solar heater, inside the drying chamber determining the preferential zone to which you want to direct the drying agent. The drying chamber was built with wood from ½ plywood "thickness and dimensions of 60 cm long, 40 cm wide, 55 cm in height. It has four trays of nylon mesh, allowing a mass of initial drying of approximately 2 kg.

The main element is a coil of sheet copper painted matte black, placed in the interior of the structure, isolated at the base and on all four sides with glass fibre wool. He has thirteen channels of 10 x 10 x 10 cm, which means a final length of 5 m in air travel to warm up, giving a flow of 0.01 m3/s to a conservative speed of 1 m/s in natural convection.

The connection between the solar air heater and the drying chamber is via a very low thermal conductivity neoprene hose on your wall.

As in all indirect Solar dryer, room temperature air enters the system through the base of the coil and raises its temperature through natural convection towards the upper part of the same, this is the function of the solar air heater.

Then hot air toward the base of the drying chamber is driven using the entrance to preferentially as the type of product that is wanted to dry and the speed which required all process, in fact, the area which should enter hot air Chamber can be at any time during the drying process as needed that is, if the process is in your home where the product moisture is on the surface of the sample, it is recommended that flow between the camera so that it can extract more moisture, while if the process is at a stage more advanced, it is preferable to flow more slowly, but at higher temperatures.

Figure 03.- Indirect Solar dryer with Variable steering flow.

4. METHODOLOGY.

For the drying of Cactus using indirect solar dryer the following steps are performed:

- Cut the Cactus transversely to the stalk in order to obtain approximately 1 cm wide segments.
- Ferment these segments in water for a period of 24 hrs.
- Wash with water.
- Position the rings about solar dryer trays.
- Allow drying.
- Measurement of the loss of mass of a sample of the product based on the elapsed time.
- Determination of the amount of dry mass (m_s) of the product.
- Behavior of loss of moisture dry basement [X=(m-ms)/ms] product based on time.
- Determination of the speed of drying [V=(ms/A)(ΔX/Δt)]product.
- Behavior of the speed of drying of the product depending on the loss of moisture dry basement.

Figure 04.- Cross cut of the stalk of the cactus.

Figure 05.- Placement in water of the segments to its fermentation.

Figure 06.- Placement of segments of prickly pear on drying trays.

Figure 07.- Placement of the trays with the Cactus inside the drying chamber.

Figure 08.- Drying process concluded.

Figure 09.- Measurement of the loss of mass of a sample of the product.

5. RESULTS.

Taken measures of loss of mass of a sample of the product of 51.2 grs placed over an area of 100 cm^2, ending with a dry mass (m_s) 1.5 g, allowing you to determine at the end of the process the initial moisture content of dry basis of Nopal "OpuntiaLasiacantha" m_s=33.13 and an average speed of drying of 0.132 g/cm^2hr).

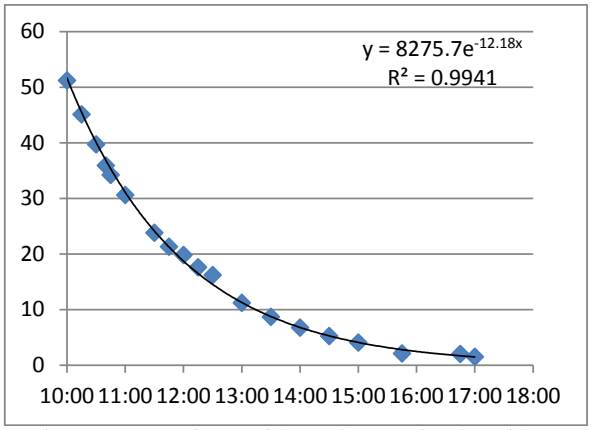

Figure 10.- Loss of mass of the product as a function of time.

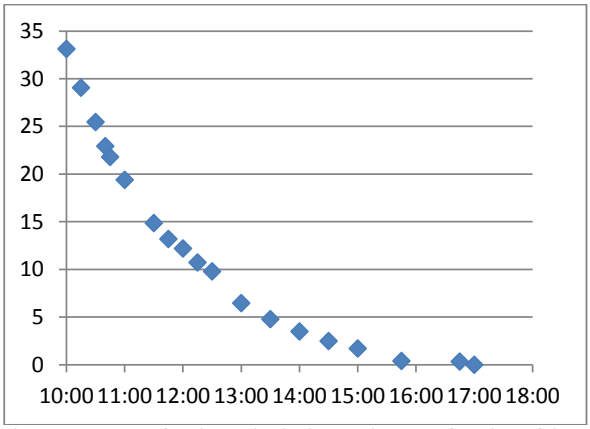

Figure 11.- Loss of moisture basis dry product as a function of time.

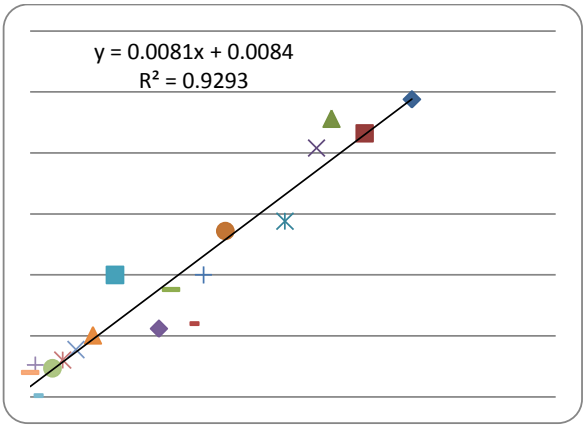

Figure 12.- Behaviour of the speed of drying of the product depending on the dry basis moisture.

6. CONCLUSIONS.

- The Indirect Solar Dryer used in this process is the right fit for Nopal drying due to the protection of the product from direct sunlight.
- The ability of this Indirect Solar Dryer and how to place the product on the trays allowed to dry about one kilogram daily Nopal.
- For the correct drying of the Nopal required a process of successful court as well as an inevitable process of fermentation and washing
- The drying rate decreases linearly from the beginning without presenting clearly somewhere critical moisture that separate the area of constant speed from the rest.
- The drying time of greater amounts of product can be estimated by using the calculation of the average speed of the entire process.

References

1. Cervantes, Mayán., “La grana cochinilla del nopal”, Editorial INAH, 2004, México.
2. Aragón Salgado, Nidia., “Respuesta postcosecha del nopal Opuntia ficus sometido a diferentes operaciones básicas”, Editorial ANDSA, 1990, México.
3. Desrosier, Norman W., "Conservación de Alimentos", Cia. Editorial Continental, S.A. de C.V., 1989, México, D.F.
4. Lacerca, Alberto M., "Industrialización Casera de Frutas y Hortalizas", Editorial Albatros, 1987, Buenos Aires, República Argentina.
5. Daniels, Farrington., "Uso Directo de la Energía Solar", H. Blume Ediciones, 1982, Madrid, España.
6. CYTED (Programa de Ciencia y Tecnología para el Desarrollo), Subprograma VI.- Nuevas Fuentes y Conservación de la Energía, “Ingeniería del Secado Solar”, Editores: R.Corvalán, M.Horn, R.Román, L.Saravia, 1983, Sudamérica.